Extract from Professor Schumacher's Astronomische Nachrichten, No. 632.

LETTER OF PROFESSOR A. D. BACHE TO THE EDITOR.

WASHINGTON, *February* 7, 1848.

The results obtained in connexion with the survey of the coast of the United States, under my direction, for difference of longitude by the electro-magnetic telegraph being of considerable interest, I have requested *Sears C. Walker*, esq., the assistant of the Coast Survey, in whose immediate charge the operations have been, to prepare a notice of them for publication; I have now the honor to forward it to you, and would respectfully request that you will give it insertion in your journal.

A. D. BACHE,
Superintendent U. S. Coast Survey.

CAMBRIDGE, *Massachusetts*, *Nov.* 10, 1847.

To Professor A. D. BACHE, LL. D.
Superintendent U. S. Coast Survey.

SIR: In compliance with your request, I forward to you a notice of the telegraphic operations for longitude comprising the substance of my report as far as completed. The final discussion of the observations for clock corrections by least squares is in progress, but not completed.

Your instructions for making the necessary preparations for passing telegraph signals, for the purpose of determining geographical longitudes, were received in the autumn of 1845. Arrangements for using the Jersey City and Washington telegraph line were made with the honorable Amos Kendall, in January, 1846. Wires connecting the main lines at Washington with the Washington Observatory were put up by the United States coast survey, in the summer of that year, and telegraph signals were passed between Philadelphia and Washington, on the 10th and 22d of October, 1846. More complete apparatus having been procured, experiments were renewed in July and August, 1847. Lieutenant *Maury*, Superintendent of the National Observatory, directed the co-operation of that establishment.

The services of Professor *Kendall*, Director of the Observatory of the Central High School of Philadelphia, had been engaged. Finally those of Prof. *Loomis* of the New York University had been engaged to superintend the observations at the temporary station of the U. S Coast

Survey in Jersey City opposite New York. Your instructions placed the arrangements of the details of the operations under my immediate charge.

After 10 o'clock P. M. the three stations just mentioned were, by means of the apparatus of the Coast Survey, converted into temporary Telegraph offices, as well as astronomical stations.

The astronomical observations for clock corrections and personal equations were arranged on the model of *Struve's* celebrated Chronometer Expedition between Pulkova and Altona.

The mode of transmitting *Morse's* telegraph signals was very simple. A mean solar chronometer was compared by coincidence of beats with the sidereal Transit clock, before and after Telegraph signals. Then the party giving signals having previously broken the circuit restored it by striking on his signal key, at intervals of even ten seconds for a period of about ten minutes, so as to ensure at least one coincidence. The party at the other station who received the signals, was notified of each signal beat by hearing his own armature beat. The apparatus was adjusted so that the receiving armature beat should be nearly as loud as the clock beat. The times of the armature beat were compared with those of the receiving sidereal clock beat by the ear alone, and the time so recorded. On some nights the signals, only twenty in number, were given at each ten seconds of the signal sidereal clock. But this method only repeats on the receiving clock the same fraction of a second, and does not furnish the same precision as the method of coincidence of beats.

Let us suppose that the Eastern Observer sends his Signal key beat expressed in sidereal time of the meridian of Greenwich,

$$\sigma = T + \omega - rt + d + \epsilon$$

and the Western Observer receives and records in time of the same meridian the accented quantities,

$$\sigma' = T' + \omega' - r\,t' + d' + \zeta' - \eta' - \theta'$$

where t = the interval from the date T to the date for which the clock correction is computed.
d, d' = the longitudes (+ east, — west) of Greenwich of the eastern and western stations,
ϵ = the correction of the personal error in *giving* signals,
ζ = the same in *receiving* signals,
η = the *circuit* time,
θ = the receiving *armature* time,
ω = the clock correction, freed of personal equation of observer.

Then by eastern signals,

$$0 = (d' - d) + (T' - T) + (\omega' - \omega) - (r'\,t' - rt) - \epsilon + \zeta' - \eta' - \theta'$$

and by western signals,

$$0 = (d' - d) + (T'_{,} - T_{,}) + (\omega' - \omega) - (r'\,t'_{,} - rt_{,}) + \epsilon' - \zeta + \eta + \theta$$

Making

$$\varphi = T + \omega - rt; \qquad \varphi_{,} = T_{,} + \omega - r\,t_{,}$$
$$\varphi' = T' + \omega' - r't'; \qquad \varphi'_{,} = T'_{,} + \omega' - r't'_{,}$$

there results

$$\text{by eastern signals } 0 = (d' - d) + (\varphi' - \varphi) - \varepsilon + \zeta' - \kappa' - \theta'$$
$$\text{by western signals } 0 = (d' - d) + (\varphi'_{,} - \varphi_{,}) + \varepsilon' - \zeta + \kappa + \theta$$

also making $m = (\varphi'_{,} - \varphi_{,}) - (\varphi' - \varphi)$; $n = (\varphi'_{,} - \varphi_{,}) + (\varphi' - \varphi)$

$$\text{(A)} \quad 0 = (\varepsilon' + \varepsilon) - (\zeta' + \zeta) + (\kappa' + \kappa) + (\theta' + \theta) + m$$
$$\text{(B)} \quad 0 = (\varepsilon' - \varepsilon) + (\zeta' - \zeta) - (\kappa' - \kappa) - (\theta' - \theta) + 2\,(d' - d) + n$$

The equation (*A*) is purely telegraphic. It is independent of the astronomical observations, and of the relative longitudes. It affords an important test of the precision of the work. The value of ε is nearly insensible as appears by the following table, in which it is given as nearly as could be determined by the ear of the listener.

For *Zantzinger*;	$\varepsilon = -0^s007$	No. of beats =	189
" *Kendall*;	$\varepsilon = +0.051$	No. of beats =	100
" *Keith*;	$\varepsilon = -0.003$	No. of beats =	20
" *Reynolds*;	$\varepsilon = +0.023$	No. of beats =	118
" *Walker*;	$\varepsilon = -0.001$	No. of beats =	30

These values of ε do not exceed the probable errors of the results. They authorize the conclusion that it is useless to attempt any correction of the signal times, for coincidence with the clock beats intended to be signalized, by the ear of the listener.

Where the method of coincidence of beats of a mean solar and sidereal clock was dispensed with, and a sidereal clock only was used, the value of ζ, or the estimated fraction of a second on the sidereal clock of the *receiving* observer, was sensible ; as appears from the following table, which gives the result of the first series of experiments that I am aware of on this point:

Clock Reading d. T.	LOOMIS.		KEITH.		WALKER.	
	ζ	No. Beats.	ζ	No. Beats.	ζ	No. Beats.
0^s0	+0. 00	48	+0. 00	14	+0. 00	40
1	. 03	"	. 03	"	. 01	"
2	. 09	"	. 05	"	. 01	"
3	. 16	"	. 07	"	. 02	"
4	. 18	"	. 10	"	. 06	"
5	. 17	"	. 14	"	. 08	"
6	. 14	"	. 15	"	. 10	"
7	. 10	"	. 14	"	. 09	"
8	. 02	"	. 11	"	. 06	"
9	. 01	"	. 06	"	. 03	"
Means	+0.090	480	+0.085	140	+0.046	400

Mean of 1940 results, with six persons, $\zeta = +0^s058$.

Clock Reading d. T.	KENDALL.		REYNOLDS.		MASON.	
	ζ	No. Beats.	ζ	No. Beats.	ζ	No. Beats.
0^s0	+0. 00	32	+0. 00	20	+0. 00	40
1	. 06	"	. 01	"	. 00	"
2	. 08	"	. 03	"	. 04	"
3	. 10	"	. 05	"	. 05	"
4	. 10	"	. 07	"	. 05	"
5	. 07	"	. 08	"	. 06	"
6	. 04	"	. 09	"	. 05	"
7	. 02	"	. 06	"	. 04	"
8	. 02	"	. 02	"	. 03	"
9	. 01	"	. 01	"	. 03	"
Means	+0.050	320	+0.042	200	+0.035	400

Hence it appears that observers on the average estimate the fraction of a second too small when using the ear only, unassisted by the eye. This error is also greatest at the middle date between two clock beats. It plainly indicates the necessity of relying solely on the method of coincidences of a mean solar and sidereal clock or chronometer, for which $dT = 0$; and by this table, as well as by universal experience, $\zeta = 0$.

After forming from each night's work the conditional equation (A) making $\iota = 0$, and giving to ζ the value in the preceding table, peculiar to each receiving observer when the method of coincidences was not employed, the table of the observed values of $[(\nu' + \nu) + (\theta' + \theta)]$ was formed.

Date, 1847.	WASHINGTON AND PHILADELPHIA.		PHILADELPHIA AND JERSEY CITY.		WASHINGTON AND JERSEY CITY.	
	$(\nu' + \nu) + (\theta' + \theta)$	No. Beats.	$(\nu' + \nu) + (\theta' + \theta)$	No. Beats.	$(\nu' + \nu) + (\theta' + \theta)$	No. Beats.
July 17	$+ 0^s02$	40				
19	— 0.11	"	$— 0^s09$	40		
21	+ 0.07	"				
24	— 0.16	"	— 0.30	"		
27			+ 0 08	"		
28			— 0 16	"		
29	— 0.01	"	— 0.13	"	$— 0^s03$	40
Aug. 3	+ 0.09	"	— 0.05	"	— 0.14	"
10			+ 0.15	"		
11			+ 0.20	"		
Means	— 0.017	240	— 0.038	320	— 0.085	80

Mean of sixteen results, $[(\nu' + \nu) + (\theta' + \theta)] = — 0.^s017$.

From this table it appears that the two circuit times added to the sum of the two armature times is insensible. Each quantity is necessarily positive. The negative result for the aggregate, viz., $-0^{s}017$, must be regarded as the small error of the work.

Since we find $\varepsilon = 0$ by trial, $\zeta = 0$ by the method of coincidences of beats of mean solar and sidereal clocks, and finally $[(\nu' + \nu) + (\theta' + \theta)] = 0$, it follows that *for the distance of 250 miles, embraced in this experiment, the comparison of the clocks together is effected with the same degree of precision as if they were placed side by side.*

The next tables contain the equation (B) for each of the night's works. The value of ε, ζ, ν and θ, are used as stated above.

Longitude by Telegraph signals between Philadelphia and Washington.

DATE. 1847.	By Philadelphia signals.	By Washington signals.	Mean result. (B)	No. of Stars observed at Philadelphia.	No. of Stars observed at Washington.	Relative weight.
	m. *s.*	*m.* *s.*	*m.* *s.*			
July 19	7 33.017	7 32.920	7 32.969	9	6	3.6
21	7 33.210	7 33.180	7 33.195	4	13	3.1
24	7 33.060	7 33.056	7 33.058	8	11	4.6
29	7 33.062	7 33.038	7 33.050	8	16	5.3
August 3	7 33.083	7 33.184	7 33.134	10	13	5.7
Means..	7 33.079	7 33.080	7 33.079	39	59	22.3

Jersey City and Washington.

July 29	12 3.572	12 3.532	12 3.552	6	16	4.4
August 3	12 3.505	12 3.339	12 3.452	6	13	4.1
Means..	12 3.540	12 3.468	12 3.504	12	29	8.5

Jersey City and Philadelphia.

July 19	4 30.557	4 30.322	4 30.440	6	9	3.6
24	4 30.427	4 30.182	4 30.305	6	8	3.4
27	4 30.444	4 30.461	4 30.425	7	9	3.9
28	4 30.548	4 30.393	4 30.470	5	8	3.1
29	4 30.284	4 30.530	4 30.407	6	8	3.4
August 3	4 30.473	4 30.298	4 30.386	6	10	3.8
10	4 30.438	4 30.440	4 30.439	5	6	2.7
11	4 30.242	4 30.363	4 30.303	6	13	4.1
	4 30.422	4 30.371	4 30.397	47	71	28.0

The preceding tables seem to authorize the conclusion: 1st. That *Morse's* electro-magnetic telegraph affords the best means for an astronomical determination of terrestrial longitudes between places in connexion with each other. 2d. That the two clocks may be compared together as well as if placed side by side. 3d. That the relative clock corrections for the night contain the only source of error to be apprehended.

If these points are admitted, I think we may further conclude that the relative clock corrections $(\omega' - \omega)$ may be obtained with any desirable degree of precision, by sufficient multiplication of nights of observation, and of Zenith stars observed in the two positions of the transit instrument. The personal equation of the observers $(d\omega' - d\omega)$ can be determined with sufficient precision by alternation of observers at the stations. The collection of a very extensive series of observations of the personal equation of the individuals employed in the work for 1847, indicates that this source of error far exceeds all others that are incident to the method. The reduction of any observer's clock correction for any night, to the normal value or average value for all the observers, is by no means constant. It seems to vary with the health and temperament of the observer. I have called it the temperament correction for this reason. When the alternations of observers are sufficiently numerous to eliminate this last source of error, there will remain only the error arising from the relative deviations of the plumb lines from those of a normal spheroid.

SEARS C. WALKER,
Assistant U. S. C. S.